

STATUS OF PBFA II ENGINEERING

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SUMMARY

PBFA II is a 36-module accelerator of roughly 3 1/2 times the power and energy of PBFA I. It is presently in the final design stage and is expected to become operational in early 1986.

In the two years since the PBFA II project was initiated, rapid progress has been made in many areas. Design limitations in each of the major accelerator sections have been identified. A baseline configuration was developed and has been updated twice. A demonstration experiment (DEMON) was designed and constructed to serve as a prototype module. Results from this experiment are now enabling us to quantify the design limitations and are helping us move toward completion of the accelerator design.

Major engineering issues in PBFA II include the size, weight, and support of the accelerator, switching synchronization, switching method, component placement, component peak mechanical stresses, accelerator access, experimental shot rate limitations, fault modes, and activation and maintenance of the target chamber.

Along with these technical issues, we have pursued accelerator engineering approaches and quality assurance activities which will be central to constructing and operating PBFA II successfully. These will be tested soon: the structure which will house the accelerator will be completed in July 1983, and construction of the accelerator tank will begin in the same month.

INTRODUCTION

PBFA II is a superpower generator designed to perform ignition scaling studies in the late 1980's for the inertial confinement fusion program. The objective of the accelerator is to provide energetic light ion beams of sufficient power intensity for target implosion experiments. This will be accomplished through the steps in PBFA II pulse generation, compression, and transmission listed in Table I. A conceptual drawing of the accelerator is shown in Figure 1. Pulse generation takes place in the transformer-oil-insulated energy storage section; pulse compression predominantly takes place in the demineralized-water-insulated section; pulse transmission and spatial compression predominantly take place in the central vacuum section.

1. DC charge of 1400 μ f to +100kV and 1400 μ f to -100kV in two minutes
2. Marx circuit erection and discharge of the 14 MJ stored in about 1 μ sec
3. High voltage connection of the Marx outputs to water-insulated intermediate storage capacitors
4. Synchronized, laser-triggered gas switching of the energy into water-insulated, pulse forming lines
5. Compression of the power pulse to 40 ns FWHM using water-switched elements
6. Spatial convolution and transmission of the pulse to a vacuum insulator stack
7. Spatial convolution in vacuum and transmission of the pulse to an ion diode

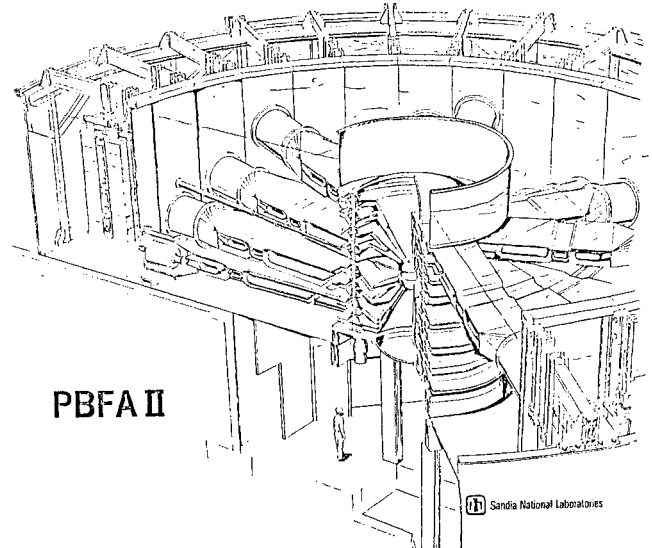


FIGURE 1: PBFA II

At present, the accelerator engineering design is at the midway point. Technical design limitations have been identified, many issues have been resolved, but others remain. A list of milestones passed to date is presented in Table II.

PBFA-II MILESTONES

| | |
|---|---------------|
| CONCEPTUAL DESIGN | MAY 1981 |
| FIRST ROUND OF LAYOUTS | JUNE 1981 |
| CHOICE OF BASELINE WATER-LINE CONFIGURATION | JULY 1981 |
| DECISION TO PROCEED WITH DEMONSTRATION (DEMON) EXPERIMENT | AUGUST 1981 |
| DEMON TANK DESIGN COMPLETED | NOVEMBER 1981 |
| PBFA-II PHASE B MODIFICATIONS INCORPORATED | DECEMBER 1981 |
| DEMON MARX DESIGN COMPLETED | JANUARY 1982 |
| PBFA-II TANK DESIGN COMPLETED | MAY 1982 |
| DEMON TANK CONSTRUCTED | MAY 1982 |
| DEMON MARX INSTALLED | JUNE 1982 |
| DEMON TRANSFER SWITCH INSTALLED | AUGUST 1982 |
| PBFA-II TANK CONTRACT AWARDED | NOVEMBER 1982 |
| DEMON PULSE FORMING SECTION INSTALLED | MARCH 1983 |
| PBFA-II TANK STEEL EMBEDMENTS INSTALLED | APRIL 1983 |
| COMPLETION OF PHASE B | JULY 1983 |
| BEGINNING OF PBFA-II TANK CONSTRUCTION | JULY 1983 |

TABLE II: PBFA II Milestones

TABLE I. PBFA II Accelerator Operation

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DESIGN LIMITATIONS AND STATUS OF ACCELERATOR ENGINEERING

Design limitations have been sought out since the beginning of the project so that a consistent design, which minimizes the extent of the technical compromise in any single section, can be developed. These limitations are listed in Table III. Their effect has been to limit the available design space and require that decisions between several alternative options be made as early as possible. They are briefly discussed below.

1. Size, weight, and support of the accelerator
2. Switching synchronization
3. Component placement
4. Component mechanical stresses
5. Accelerator access
6. Shot rate
7. Fault modes
8. Cost
9. Schedule

TABLE III: Major PBFA-II Design Limitations

Size, Weight, and Support of the Accelerator

The PBFA II accelerator will be a highly powerful and versatile device in terms of its output parameters. One of the principal reasons for this is the volume available for components in the accelerator tank; the diameter is 108 feet, and the depth is 20 feet. The tank itself consists of more than 250,000 kg of structural steel and is supported by a substructural floor of the same weight. (See Figure 2.)

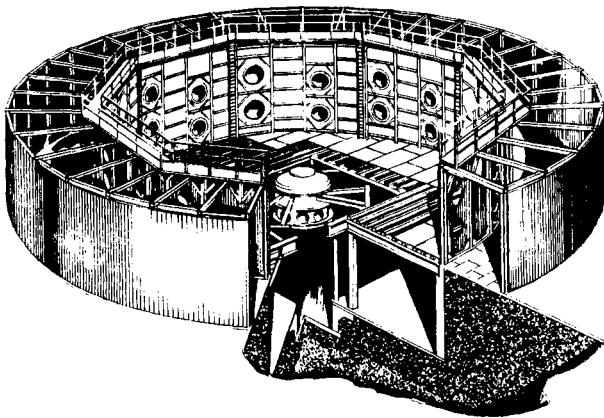


FIGURE 2: PBFA II Accelerator Tank

The substructural floor is fairly massive due to the requirement that it support the tank central structure and vacuum interface stack and, unlike PBFA I, the water section over a large pit beneath the accelerator which is used for component access, fluids filling and draining, and machine servicing. In PBFA II, the insulating oil (650,000 gal.) and the deionized water (600,000 gal.) weighs 2.3 million kg and 2.5 million kg, respectively. The structural designs of the tank walls and the supporting floor were analyzed extensively using a finite element model with various assumptions for static and dynamic loads.

The status of the accelerator tank is shown in Table II. On-site erection will begin in July, 1983. The DEMON accelerator tank, which was designed to simulate 20° of PBFA II, permits "full-depth" energy storage component development and "full-length" pulse forming component development of one PBFA II module.

Switching Synchronization

The baseline design for the last synchronized, externally-triggered switch in each accelerator module, which determines the synchronization of the output power pulses to a large degree, is a laser-triggered, SF₆-insulated, multistage switch. The engineering design which provides laser pathways for triggering of 36 switches at 6 MV from one main laser is required to be simple, cost efficient, adjustable, and sufficiently stable that realignment between accelerator shots is not necessary. A layout of the beam turning locations, in plan and elevation views, is shown in Figure 3. Mechanical features of one of the nine laser standpipes, key elements of the system, are shown in Figure 4.

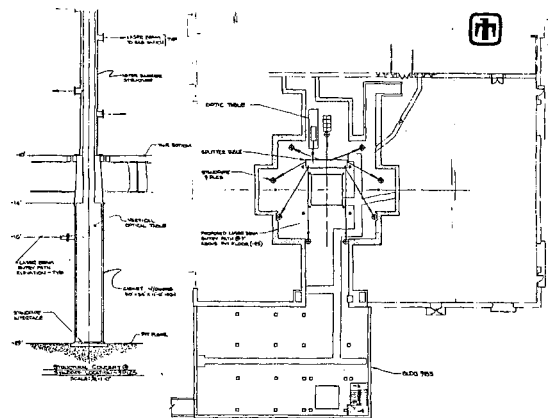


FIGURE 3: Beam Turning Locations In The Laser Trigger System

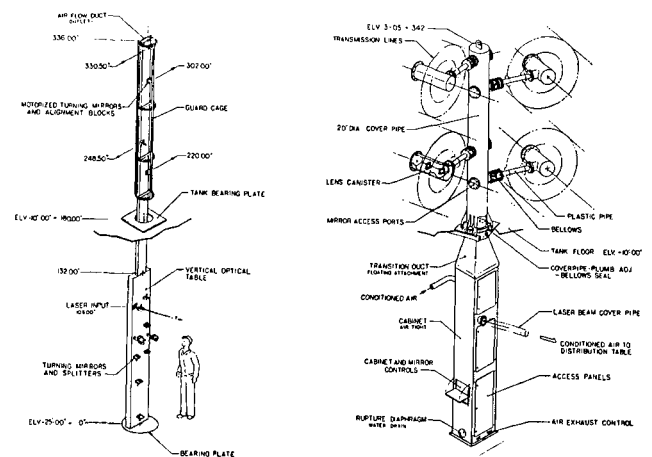


FIGURE 4: Mechanical Features Of The Laser Standpipes

Component Placement

Placement of components in the accelerator is shown in the elevation view of Figure 5. The vacuum insulator stack, consisting of eight modules, is driven by a four-layer split-line pulse forming section. To ease maintenance, these layers are staggered vertically and located at 20 degree intervals. The energy storage section holds a Marx generator in each 10 degree sector. An elevation of this section, showing component placement, is shown in Figure 6.

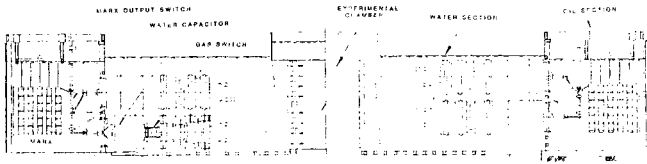


FIGURE 5: Elevation View Of The PBFA II Accelerator

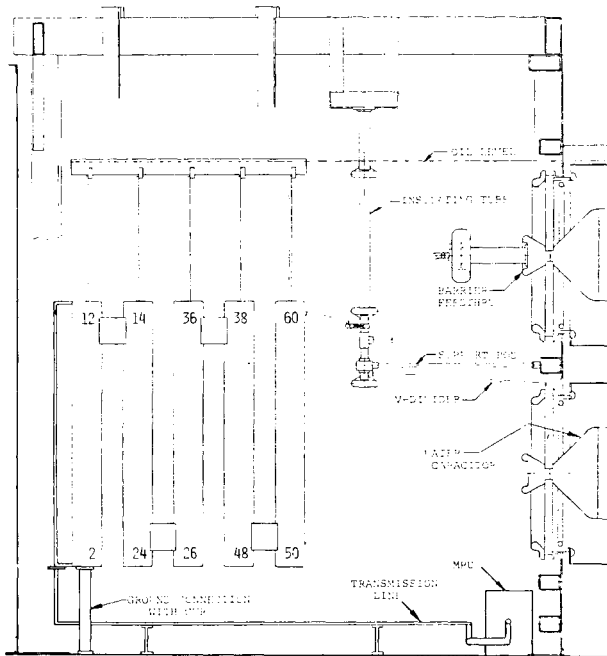


FIGURE 6: PBFA II Energy Storage Section

Component Mechanical Stresses

Significant design limitations in the area of mechanical stresses have to include, besides fluid weights, the water shock due to water switching internal to the coaxial PFL structure (about 100 psi), the water shock at the tank floor, and both the pulsed and static stresses at the vacuum insulator stack. An example of these latter stresses is given in Figure 7.

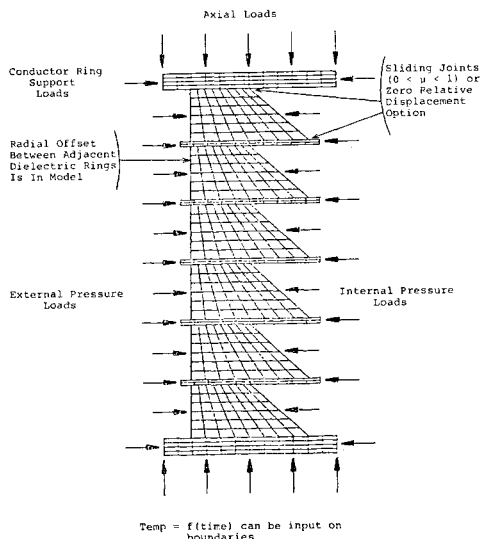


FIGURE 7: PBFA II Vacuum Interface Static Stress Analysis

Accelerator Access

PBFA II has been designed with maintenance as a foremost consideration. The large pit beneath the accelerator, placement of components, and work platforms in each section of the accelerator will contribute to improved maintenance capability and higher data recovery.

Experimental Shot Rate

The experimental shot rate limitations which can be foreseen at this time include refurbishment and replacement of the diode, alignment of the diode within a large insulator stack, diagnostics placement, and target chamber evacuation. Mechanical removal of small bubbles from high electrical stress areas in the water-dielectric pulse forming section will still be necessary due to entrapment of entrained air during filling, but will be minimized by a deaeration loop included in the water processing system.

Fault Modes

The fault modes of highest consequence in PBFA II which can be postulated are shown in Table IV. The mechanical and electrical design of these elements has taken into account reasonable factors of safety, and design is continuing.

1. Marx Generator Prefire
2. Oil/Water Barrier Tear, Rupture, Or Burn-Through
3. Water Arc
 - Within A PFL
 - At A Gas Switch
 - At The Vacuum Insulator
4. Vacuum Insulator Rupture
5. "Instantaneous" Loss Of Vacuum
6. Dropping A Major Component Due To
 - Crane Failure
 - Hardware Failure
 - Operator Error

TABLE IV: Significant "Recognized" Accelerator Fault Modes

Activation and Maintenance of the Target Chamber

If ignition is achieved on PBFA II, the neutron dose to the diode, diagnostics, vacuum interface dielectric and grading rings and vacuum covers will be significant. The heaviest dose will be incident upon the diode, which will also require the most frequent refurbishment. Aluminum will be used to the greatest extent possible, rather than steel or brass, so that hands-on maintenance may begin within 24 hours of a major neutron-producing shot. For high-level shots, neutron activation could be a significant limitation on the possible shot rate.

PBFA II ACCELERATOR ENGINEERING APPROACH

The elements of accelerator engineering which we are using during the PBFA II design and construction period are shown in Table V. Key items in the list include criteria reviews and sequential design and drawing reviews. These reviews are instrumental in resolving design issues before moving to the next level of hardware development. Evolution of accelerator hardware for a multimodular accelerator typically proceeds through several stages, as listed in Table VI. In several instances on PBFA II, engineered

- Pre-conceptual Design
- Conceptual Design
 - Criteria development
 - Criteria review
- Preliminary Design
 - PDR
- Final Design
 - FDR
- Final Drafting
- Drawing Sign-off
- Procurement
- Fabrication
 - Field Monitoring
- Delivery & Inventory
 - Inspection
- Assembly and Installation
- Subsystem Tests
- System Tests
 - Final documentation

TABLE V: Elements Of Accelerator Engineering

1. Research Hardware
2. Engineered Hardware
3. Prototype Hardware
4. Production Hardware

TABLE VI: Stages Of Hardware Evolution

hardware and prototype hardware are the same. In cases where significant modification is required after a test series, they are separate.

Engineering Modeling

We have learned that an attractive means of determining component layouts, resolving interface conflicts, and uncovering errors in final drawings early, quickly, and at minimal cost is available through scale modeling. Different types of models suit different needs. A brief description of model types and utilization is given in Table VII.

1. Block Models
 - Used during conceptual design phase to plan and lay out components, and to begin system layout drawings
 - Primary use: Space utilization
2. Preliminary Models
 - Used during preliminary design phase to display and test various hardware concepts
 - Primary use: Component and system integration
3. Check Models
 - Used during final design phase to check accuracy of engineering drawings
 - Primary use: Uncover errors

TABLE VII: Types Of Engineering Design Models

Quality Assurance

In a project of the scope of PBFA II, quality assurance is an essential prerequisite for meeting cost, performance, and schedule objectives. Quality control of hardware during fabrication is only a small portion of quality assurance. The remaining elements are listed in Table VIII. First and most important among these is the dedication of highly skilled engineers, without whom execution of a major project is impossible.

1. Highly-Skilled, Dedicated Engineers
2. Drawing Control
3. Check Modelling
4. Technical Award Criteria For Procurement Of Key Items
5. Survey Of Qualified Vendors For Procurement Of Major Items
6. Early And Frequent Vendor Site Visits

TABLE VIII: Major QA Elements

CONCLUSION

In conclusion, there are three points to be made relative to the status of PBFA II engineering:

1. We are mid-way in the design of the accelerator and tank construction is now beginning.
2. Most of the important accelerator limitations have been identified and solutions to design problems are being developed.
3. We are attempting to maximize our chances of performing ignition scaling studies on PBFA II later in this decade, and are eagerly looking forward to the excitement of the next few years.